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ABSTRACT

Although the quality of educational software is increasing dramatically, the need for good instructional software far surpasses the supply. There are at present relatively few authors with the array of knowledge and skills necessary to produce high quality interactive instruction. In the absence of trained authors, much of the available software has been produced by teams of experts who typically have little experience and knowledge. This paper explores the range of skills that may be desirable for creating effective instruction with the electronic media, examines the drawbacks of existing methods of authoring instructional material, and considers the kinds of curricula that would provide education and training in the requisite skills. A course of study is envisioned which would educate "master authors" in: (1) subject matter expertise; (2) artistic and technological skills; (3) instructional design skills; and (4) information processing and learning theory. A 17-item bibliography and brief biographies of the authors are included. (Author/JB)

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EDUCATING MASTER AUTHORS FOR DESIGNING INSTRUCTION WITH THE NEW ELECTRONIC TECHNOLOGIES: THE MAKING OF MICHAELANGELOS

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Abstract

Although the quality of educational software is increasing dramatically, the need for good instructional software far surpasses the supply. There are at present relatively few authors with the array of knowledge and skills necessary to produce high quality interactive instruction. In the absence of trained authors, much of the available software has been produced by teams of experts who typically have little overlap in experience and knowledge. A curriculum is proposed to provide a composite education for 'Master Authors' in domain specific (content) knowledge, the knowledge structure of the field, learning and information processing theory, procedures and tools for generating materials, style and form, and research methods.

1. INTRODUCTION

This paper explores the range of skills that may be desirable or essential for creating effective instruction with the electronic media, examines the drawbacks of existing methods of authoring instructional material, and considers the kinds of curricula that would provide education and training in the requisite skills. We envision a course of study to educate individuals in --

(1) subject matter expertise,
(2) artistic and technological skills,
(3) instructional design skills, and
(4) information processing and learning theory.

Such composite training is not currently available through formal education programs in the U.S. or elsewhere, nor is it readily acquired by apprenticeship or other informal methods.

2. NEED FOR AUTHORS

The need for improved education in the U.S. is demonstrably clear (see, for example, 8). However, although this view is widely accepted today, there is considerably less agreement about what are the best means for achieving the needed improvements. We feel that the new electronic techologies are potentially our most valuable tools for improving the quality of education at all levels. This paper is not intended to argue this point of view, but nonetheless a few of the most compelling reasons leading to this conclusion are listed below.

Cumulativity & Dissemination. Most teaching/learning process are conducted in cottage industry fashion. Great teachers come and go, and their impact is largely limited to a geographical place and chronological moment. The printing industry permitted significant gains in the potential impact of a good teacher through the production and dissemination of texts and other books. Computer technology has the dissemination capability of the printing press, making the best instructional materials widely accessible.

Creative Expression. The computer can be viewed as a powerful medium, like a pencil, brush, or musical

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instrument. Put in the hands of children, the computer can inspire and facilitate a wide range of personal expression. This provides practice and integration of learned skills.

Individualization. A text can be used differently by different individuals, just as a computer can. But the computer has an added capability. It can also respond differently, and this creates a powerful potential for individualized diagnoses and personalized instruction.

Cost. The U.S. has witnessed 200 years of steadily escalating costs of education, and recently, declines in achievement. As a powerful teacher's aid, computer technology can help to reverse both of these trends.

Critics of the usefulness of computers in education raise such issues as the relatively low quality of existing educational software, unequal access by rich and poor, and differential responses by males and females. These are, indeed, serious concerns, but we believe they can be resolved in a relatively short period of time. Increasing computing power in combination with trained, talented teacher-authors (the topic of this paper) will produce better software; declining computer costs will increase accessibility; and creation of programs that appeal to female values and perspectives will reduce the sex biases.

For the purposes of this paper, we assume that the reader generally accepts these points of view. The questions we focus on here are, assuming that educational software is to be produced on a large scale with the computer and the videodisc, what kinds of authoring talent do we need and how should authors be prepared?

3. MASTER AUTHORS: TALENTED, TRAINED & SKILLED PROFESSIONALS

The most significant limiting factor in educational applications of computers and computer-related technologies is the paucity of high quality software and courseware. This limitation stems in turn from a variety of machine and human variables -- the most critical (in our judgment) being the lack of talented and skilled authors and the absence of an environment conducive to their productivity.

The challenges of authoring materials for/with the new technologies are compounded by the breathtaking rate of technological advance. Hardware innovations dramatically change what is possible. For example, the laser videodisc permits one to combine still pictures, graphics, text, moving pictures, and intactive dialogue/testing into a single instructional program. Associated with rapid changes in hardware are advances and modifications in programming languages and programming techniques. While these often provide greater programming ease and power in the long run, in the short run they exacerbate the problems of program creation and maintenance.

Designing good instruction for interactive electronic presentation is a demanding task that requires substantial knowledge of both subject matter content and of the processes of teaching and learning. This knowledge needs to be integrated into a unified vision of what is being attempted (in producing a particular instructional program) and what means will be employed.

In addition to this well-integrated knowledge, authors for the new instructional technologies should have imaginative and creative vision. This is essential for the development of fresh, new approaches to instruction, approaches that capitalize on the unique capabilities of current and future electronic technologies. Without creative vision there is a tendency toward the 'horseless carriage' syndrome -- as when electronic technologies are used to mimic traditional methods of teaching rather than realizing what is possible now that was not possible before.

In sum, we envisage a Master Author who is a modern Michaelangelo, a combination of artist, scientist, scholar - a highly talented, trained, and skilled individual with a broad range of knowledge. Just as a medical doctor must know a good deal about anatomy, physiology, genetics, endocrinology, biochemistry, immune response, infectious agents, psychology and a host of other

subjects, so a Master Author must know a good deal about the subject being taught; the learning skills and styles of the intended students; the mechanisms of interest, attention, motivation, and information processing; the capabilities and limitations of the electronic media; and a host of other topics.

Is it really necessary to envision yet another professional, you may ask, one on an educational par with doctors, lawyers, and engineers? We believe the answer is an emphatic YES. Our reasons are summarized in the next few sections.

4. THE AUTHORING PROCESS

Systematic instructional design involves the transition from a concept, such as independent assortment in genetics or relativity in physics, to the final assembly of the words, images, sounds, problems, events, assignments, questions, test items, stories, events, discussions, demonstrations, examples, and explanations that make up an instructional unit. A unit may be a 15 minute segment of instruction or may be equivalent to a year-long course.

Making a list of authoring responsibilities actually does a disservice to the authoring concept, since different authors have wildly different styles. Some are very deliberate in making a plan, carrying out research, making preliminary sketches of what is to be produced, obtaining feedback, and working through successive versions. Others are much more intuitive and talk about how their task 'takes command of them' and directs each successive step. Some authors work backward from a secure goal while others move forward, one intuitive step at a time, having only a vague feeling that each step is correct. It is dangerous to overly constrain a creative process that is so poorly understood. With this cavaet, the following tasks are offered to illustrate the range of performance required of the 'Master Author':

(1) Define what is to be taught -- explicitly and implicitly.

(2) Decide what is to be presented to the student, i.e., what events, demonstrations, explanations, examples, stories, procedures, etc., are to be included.

(3) Decide what guiding statements will be given. Frase (9) has shown that specific guiding statements, such as "Pay attention to the verbs in the following paragraph," significantly affect what students learn from a passage. We assume that similar clues are embedded in non-verbal stimuli.

(4) Decide what affective or motivational elements will be incorporated into the instructional process. The author should orchestrate a variety of methods for increased interest, commitment, and persistence.

(5) To the extent feasible and reasonable, define the instructional environment. This includes social factors (Will groups of students work together on a project?) as well as factors aimed at the individual characteristics of different students.

(6) Perhaps most important, decide what the student will be expected to do in response to the presentations (An instructional unit with reading assignments followed by fact-recall tests would, we propose, have different outcomes from one in which students must analyze and solve real-life problems).

(7) Determine how the response of the student is to be evaluated. How will the student know whether s/he has grasped the important ideas? How can we and the student discover the student's preconceptions, misconceptions, faulty models, and the boundaries of their knowledge?

(8) Select the media to be employed and specify the ways they are to be used. Either plan, sense, or envision the flow, rhythm, and texture of the entire sequence.

(9) Have a 'feel' for how the intended students will react to the elements, whether they will be challenged, how they will cope with difficulties in understanding, and how their frustrations will affect their acquisition of skill and knowledge.

(10) Determine the contingencies that should follow various kinds of student responses (e.g., move to another exercise, select from a menu, try the same exercise again, discuss the result with a classmate).

(11) Identify, gather or produce the materials needed (object , pictures, drawings, graphs, other representations, quotations, music, spoken passages, motion sequences, demonstrations, explicitly beautiful materials).

(12) Compose an instructional program, picture by picture, program line by program line, word by word, weaving a rich, interesting, and instructive texture.

(13) Evaluate pilot versions of the instructional product. Evaluation methods may include such approaches as peer review, review by intelligent novices, in-depth studies with small numbers of learners, measures of learning gains with large groups, analyses of videotapes and audiotapes of student-program interactions, and interviews with students and teachers.

(14) Revise the instructional programs until, within constraints of resources, time, and timeliness, they meet the author's and publisher's quality criteria.

(15) Conduct research aimed at gaining a fundamental understanding of what happens in the instructional process.

(16) Judiciously invest in a limited and controlled effort to document, analyze, and interpret what happens when materials are marketed and used in a variety of contexts. In other words, try to learn from experience. Pay attention to anomalies, events that are either a total surprise or that are different from what one expected.

(17) Use research, evaluation, and analysis to generate new hypotheses for explaining and predicting learning behavior with greater specificity and accuracy.

To summarize, the tasks to be performed by a Master Author require a deep, integrated (not superficial or halting) knowledge of the subject being taught, a practical as well as theoretical understanding of the medium being used, and the best current knowledge of the learning process. It is our contention that only with this kind of talent will we create, at affordable cost, instructional materials that will capture the promise offered by the new technologies. The creative process can be pushed to its limits only if the fundamental elements cease to get in the way.

A Master Author is expected to work with speed and fluency in coordinating a wide range of knowledge. The process is similar to that of a musical composer, who must know the musical idea, the properties of sound, musical notation and theory, the capabilities of each instrument, how the instruments interact, and much more. The detailed knowledge must be so well incorporated into the mental framework of the composer that it is second nature, like one's mother tongue, and can be called upon with facility and ease.

The challenge for the Master Author is to invent new ways of teaching that capitalize on the inherent characteristics of the new technologies. This may sometimes result in teaching old knowledge and skills in new ways, and other times lead to teaching new skills that could not be taught before. For example, Papert created turtle geometry (15) to capitalize on the logical power of the computer, developing a learning environment to help teach geometry to young students.

Other new directions are suggested by the fact that the combination of the computer and videodisc permits instruction in a wide range of pro-

cedural skills that depend upon a visually-rich environment (e.g., simulation of a scientific experiment or a manual task such as piloting an airplane). The dental diagnosis simulations of the University of Nebraska (12) and the medical diagnosis simulations of WICAT (7) are examples of this development. Much of cognitive science research points toward yet another direction, that of using the new technologies to teach problem-solving skills (2, 5, 17).

5. AUTHORING CONGLOMERATES

According to neo-Darwinian theory, there is always a lag time in natural selection. Once the environment changes, producing new selective pressures, it exerts its effects on successive generations of organisms. Gradually, the population is molded to meet environmental demands. In the interim, organisms sometimes create interesting behaviour patterns and liaisons in order to survive.

This theory seems equally applicable in education today. The American environment has been changing dramatically as powerful electronic tools have become available. The educational community has been slow to respond, in part because there were no (or few) Master Authors prepared to work with the new media (because no such need previously existed). The pressures on the educational community to (a) improve the quality of education and (b) adapt to the modern world were at first apparent only to a minority of individuals, the innovators. They responded in the best way they could given their limited resources; they employed opportunistic strategies and formed conglomerates (euphemistically called "teams") having some or all of the necessary creative, intellectual and production skills. This approach became the 'standard' for producing television and computer-aided instruction at such model institutions as The British Open University/BBC (16), the University of Mid-America (11), and the TICCET computer project (1,4).

Teams have many redeeming features, and big projects necessarily require teamwork. Atomic accelerators, space shuttles, and moon landings are examples of complex scientific projects which can only be done by large numbers of individuals working together. However, it is one thing to form a team of people who share much of the knowledge and a common set of goals with other team members. It is quite a different matter (an evolutionary expedience) to create effective teamwork when each team member initially knows almost nothing about the field of expertise of the others. This has been the bane of many authoring 'teams' (conglomerates).

Although these authoring 'teams' collectively represent considerable breadth and depth of knowledge, skills are unevenly distributed and members are often unable to communicate effectively. Each person has their own specialized jargon and worldview, and sometimes has little respect for or appreciation of the others' points of view. Further, each tends to be motivated by a different set of goals and sub-goals.

The members of such authoring conglomerates often speak what are, in effect, different languages. A great deal of time is invested in arguing, seeking control of the process, persuading, negotiating, compromising, or simply trying to understand what is happening. Frustration levels are high. Those who know the technology usually know little of teaching strategies or of the subject being taught, and are often enamored with the medium. Those who know the subject may not know how to teach through the technology and they may not appreciate either the potential or the limitations of that technology. The instructional designer may have no idea of (a) how the structure of the discipline being taught should alter the instructional process or (b) how the subtleties of a particular point might best be rendered. Thus, while the requisite combined knowledge is present in a course team, the critical connections are often not made.

As a consequence, production by conglomerate tends to be tension-filled, slow, and expensive. Furthermore, since the method necessarily involves

compromise and consensus, it tends to inhibit rather than unleash creativity -- at a time when (in our judgment) creativity is most needed! The conglomerate approach has certainly been better than doing nothing, but it is particularly poorly suited to this period of transition, when we are groping to discover the highest and best means of utilizing powerful new technologies.

The evolution of the authoring conglomerate derived from recognition of (a) the complexities of electronic production, (b) the importance of instructional design, (c) the value of evaluation and feedback, and (d) the initial disinterest by subject matter experts in acquiring knowledge of these domains. Elaborate projects have sprung up involving marriages of convenience between all sorts of unlikely specialists.

One consequence of this development is that whole cadres of individuals (television producers, instructional designers, and computer programmers, for example) are now in place and understandably interested in defending their roles. Fortunately, they do still have important roles to play, although those roles will be modified by the evolutionary process.

We should point out that not all joint development projects done to date are of the conglomerate type described here. Certainly there have been instances where all participants acquired a broad knowledge of the component skills of teaching production and shared enough of the same goals so as to form effective teams. There have also been projects led by self-taught Master Authors. Dr. Alfred Bork at the University of California - Irvine exemplifies this approach. These instances and examples point the way to the future.

As pressures continue to increase for integration of modern electronic technologies into the educational process (and they <u>are</u> increasing), recognition of the problems becomes more widespread. This permits a greater allocation of resources to solving the problems, leading to long-range evolutionary strategies. The most obvious general strategy we can anticipate is specialization. One path toward specialization is described below.

6. FOSTERING CREATIVITY & TEAMWORK

History has demonstrated that creative genius can be attracted to (or discouraged from) a particular field, can be provided tools and ideas, and can produce outstanding work as a result of being immersed in a stimulating, challenging, and supportive environment. The development of molecular biology in this country is a positive example. This, we feel, is what must be done for the new instructional technologies.

Human beings are always constrained by the mental images they carry in their brains, images necessarily built from past experience. To make a significant change in our mental frameworks, or to take a significant departure from the old worldview, can be agonizingly difficult. Because of this, new technologies tend to mimic old ones. The internal combustion engine is viewed as a 'horseless carriage', computer logic is used to turn pages of text, and television is used to transmit a lecturing teacher. When instructional materials produced for a new technology mimic the instructional designs appropriate for more familiar media (such as a teacher, a tutor, or a book), the products may actually be harmful to student learning, since the emotional/psychological 'impedance match' between the medium and the message is so strong. Only gradually do new ideas emerge that permit fuller realization of the potential of the new technology. Sometimes these ideas are quite revolutionary.

A Master Author could often escape the harness of a team and work alone to produce instructional materials, much as a master scholar writes a textbook. In doing so, s/he would seek an interpretation of a domain of knowledge that would be considered accurate and well-composed by other teachers, scholars, and students, and that would capitalize on the strengths of the medium in new and interesting ways. As authoring systems become increasingly powerful, this approach becomes increasingly attractive and practical.

Working alone has numerous advantages. With this approach, there is a minimum of dissent, argument, and bureaucratic constraints on the creative process. New ideas can be thought up and put into effect immediately, without the labor of achieving group consensus. This is valuable because an idea may at times be intuitively clear to one person, but convincing to others only after it has been demonstrated. This happens because we often have tacit knowledge that we cannot express verbally. An author who works alone can engage in much more exploration and experimentation, trying out various possibilities, discarding some and pursuing others in sometimes unforeseen directions.

The price of playful and original exploration, of course, is that not all intuitive ideas will be successful. The steady, plodding, predictable outcomes of well-managed conglomerates may be replaced by a collection of "highs" (clever, creative insights) and "lows" (ideas that didn't work). We believe this price is worth paying, since the major challenge at this point in time is to discover as many new and exciting ways as possible of utilizing the new media.

There is ample opportunity for review and quality control through discriminating acceptance, revision, rejection, and review of the published result. The cost of rejection of an individual author's work is tolerable. (In contrast, conglomerate productions often must be and are accepted even when they are dismal failures, just because so many resources were invested in them). Production of instructional materials for mass distribution will always require the efforts of many people: publishers, distributors, printers, disc manufacturers, producers of visual materials, etc., and each represents a point of potential quality control.

In summary, our point is that risks of innovation are more easily taken by the solitary creator; exploration and mental play with ideas are more likely to be engaged in and expressed. We are not embarrassed to claim that there is a need for creative talent equivalent to Mozart, Michaelangelo, van Gogh, and Einstein, to discover new ways of teaching made possible by the new media. Once we have a rich supply of masters and masterpieces, lesser artists can produce many good lessons by following their examples, working either as individuals or in teams.

Even when the size and scope of a project mean that a single Master Author will not execute all tasks, s/he should have sufficient vision and detailed knowledge of the component processes to provide effective leadership and direction for the team. A team composed of Master Authors could invoke a spirit of collective competition and creativity characteristic of many of the groups now working in industry (as, for example, described in 10). A team composed of a variety of specialists under the leadership of one or more Master Authors should perform far better than the old conglomerate of specialists (lacking secure, integrative leadership).

Teamwork does tend to assure an instructional product that is relatively non-controversial and representative of a broad point of view. Representing, as it does, the common demoninator upon which team members could agree, it eliminates much that is idiosyncratic and trivial. It may be the best approach to producing instructional materials for well-established technologies in spite of the high costs -- so long as the necessary resources are available. With Master Authors as team leaders, the collections of individual contributions may be better molded into fluent wholes.

7. AUTHORING TALENT

Talent is the key word. Programs must be designed to attract the brightest, most creative, most imaginative individuals. The program should then stimulate these people to apply their talents to the production of instructional materials with/for the interactive technologies and to push themselves to the limits of their imagination and resources. To achieve this, an environment should be created that encourages risk-taking and maintains a strong goal orientation toward the production of superior instruction.

The medical profession offers strong incentives in the form of high salaries, impressive challenges, and unlimited opportunities for the personal satisfactions associated with making significant contributions to society. Students typically begin their orientation toward and preparation for medical careers in high school. Many more students are attracted by these incentives than the field can accommodate, and the college years are spent in earnest (and anxious) competition for the available positions. The end result is that medical schools can select from an array of the brightest and best students available, all having solid foundations in relevent subject areas as well as, in many cases, related field experience. These students are then exposed to four to eight more years of education and practical training.

The field of instructional authoring can offer similar incentives: high salaries and stock options, impressive challenges, and opportunities for making significant contributions to society. Though it will not have the fascination of the life-and-death decisions of medicine, we feel it has enough attractive features that it could follow the medical model of attracting, selecting, and training talent. There are many parallels in terms of the breadth and depth of knowledge to be assimilated and the necessity of practical, hands-on proficiency at the end of the educational pipeline.

B. DOMAINS OF AUTHORING KNOWLEDGE

In order to be able to perform the tasks described in the authoring process, as well as others that haven't been anticipated, each Master Author must be rigorously trained. We have identified six major areas of expertise to be mastered, as described below.

Domain Specific Knowledge. Current research reveals that domain specific knowledge is essential for outstanding performance in that domain. A good problem-solver in medicine may be very poor at solving problems in physics or auto mechanics. There is considerably less transfer of learning and skills from one area of expertise to another than was previously recognized. There is also evidence that different disciplines require different teaching and learning methods, and that a deep appreciation of the structure of a particular discipline is a prerequisite for designing effective instruction in that discipline.

Knowledge of Knowledge Structures. The Master Author should not only know the discipline being taught, s/he should have a firm grasp of the structure of knowledge in the field. Cognitive science research, such as the studies by Brown and VanLehn (2), Davis and McKnight (6), and McCloskey et al (13), illustrate the importance of the knowledge structure in the learning process, and consequently in the design of effective instruction. This involves analyses of relationships and methods that go beyond those generally considered by a researcher working in the field.

Knowledge of the Learning Process (or 'understanding understanding', to borrow a phrase from 14). We do not yet have a strong, coherent theory of learning (although the emergence of such a theory within the next few decades seems likely). In the meantime, Master Authors should be fully informed about those fragments of relevant theories and important research findings which do exist. This includes, in our view, in-depth knowledge of cognitive science and a high degree of familiarity with the cognate disciplines such as psychology (especially concerning motivation, memory and retrieval, perception), human development (especially with respect to learning stages, misunderstandings, ability to handle abstractions, ability to solve classes of problems), neurophysiology and education. Master Authors should also have a solid base of practical experience in teaching students in the age groups of interest to them.

Knowledge of the Tools. The Master Author should be acquainted with the procedures and tools that can be used to generate primary materials, and must be familiar with the intermediate procedures employed in producing the final product. This

includes working knowledge of cameras, recorders, computer graphics, animation, color materials, electronic editing, etc. It also includes fluency in library research (including film, slides, videotapes, and computer programs as well as printed documents). Knowledge of film, video, and computer production techniques are a must. The author should be able to plan for various delivery systems, such as closed circuit TV, satellite, cable, broadcast, computer network, videodisc, and telephone transmission. This knowledge is critical if the author is to select wisely from among the wide array of available tools and methods.

Knowledge of Style and Form. The Master Author should know a great deal about forms of communication including such topics as (1) graphic design (how to attract and hold the student's interest, how to convey information succinctly and clearly), (2) readability, (3) legibility, (4) page layouts, (5) branching pathways, (6) sound effects, and (7) alternative forms of representation. S/he should be able to assess the goal of a particular unit of instruction, analyze the demands of the subject, review the capabilities of the intended audience and of the available media, and then select and use those forms that would be most suitable and effective.

Knowledge of Research Methods. Master Authors should be equipped to conduct research on the learning and teaching of their discipline. They should be trained to conduct research regularly as part of the production process, to share their findings with others, to learn from other's findings, and to think about and contribute to the development of powerful, generalizable theory. This is needed for continuous, long-term improvements in teaching and learning effectiveness, and for optimal use of the new media.

9. AUTHOR PREPARATION

Given the vast array of knowledge that seems not only desirable but necessary, the obvious question arises: How can so much be mastered, assimilated, and integrated? The practices of premedical and medical training serve as a useful model. First, we advocate that students begin training early, in the undergraduate years, to build a solid foundation in several key skill areas (physics and psychology, for example, or biology and computer science, or chemistry and linguistics, or some such combination). Second, we envisage a very challenging program, one which begins by selecting the brightest students and which builds with undergraduate, graduate, and post-graduate studies. Third, we believe the program should include substantial hands-on research, teaching, and production experience. Fourth, the program should have a strong element of current information exchange (e.g., seminars, newsletters, visits to other laboratories and commerical sites) because the entire domain of electronic technology is moving so rapidly. Fifth, the program should include considerable opportunity and incentive for experimentation, creation, and problem solving. And finally, we recognize that some specialization will be necessary with respect to content subject, the cognate disciplines, and the media.

In conclusion, consider the way that skilled athletes master a wide variety of skills so they can perform fluently under tight constraints -- especially limited time. A quarterback once said, "We practice, practice, practice during the week so that on Sunday we can improvise without thinking." Master Authors need to develop a similar level of proficiency.

REFERENCES

(1) Alderman, Donald L. Evaluation of the TICCIT Computer-Assisted Instructional System in the Community College; Final Report Vol. 1, ETS; Technical Rpt. PR-78-70, September, 1978.

(2) Brown, J.S. and K. VanLehn. Towards a generative theory of "bugs". Cognitive and Instructional Science Series, CIS-2 (SSL-80-6), Xerox Palo Alto Research Center, 3333 Coyote Hill Road, Palo Alto, CA 94304; December, 1979.

(3) Brown, J.S. and K. VanLehn. Repair theory: A generative theory of bugs in procedural skills. Cognitive and Instructional Science Series, CIS-4 (SSL-80-8), Xerox Palo Alto Research Center, 3333 Coyote Hill Road, Palo Alto, CA 94304; August, 1980.

(4) Bunderson, C.V. Team Production of Learner-controlled Courseware, a Progress Report; in Computer in the Instructional Process: Report of an International School; Zinn, Karl L., Mefice, Mario T. Romano, Aldo, eds. Amsterdam, Elsevier, 1974.

(5) Champagne, A.B. and L.E. Klopfer. Structuring process skills and the solution of verbal problems involving science concepts. Science Education 65(5):493-511, 1981.

(6) Davis, R.B. and C. McKnight. The influence of semantic content on algorithmic behaviour. Journal of Mathematical Behaviour 3(1):39-89, 1980.

(7) "Diagnostic Challenges in Gastroenterology; Differential Diagnosis in Epigastric Pain; Produced by WICAT Systems Inc., (Orem, Utah 84057); Smith Kline and French International Co., 1982.

(8) Fisher, K. and J. Lipson. Crisis in science education. Unpublished. National Science Foundation, Washington, D.C., 1981.

(9) Frase, L.T. Prose processing. In G. Bower (Ed.), Psychology of Learning and motivation (Vol. 9), New York: Academic Press, 1975.

(10) Kidder, T. The Soul of a New Machine. New York: Avon Publishers, 1981.

(11) Lipson, Joseph. Technology and Adult Education: A Report on the University of Mid-America Experiment" in The Journal--Technological Horizons in Education; Vol. 4, No. 6, September/October, 1977; p. 36.

(12) Lipson, L. Authoring Guidelines for Developing Computer Assisted Dental Simulations. Lipson, L. Ed.; PLATO Project; University of Nebraska Medical Center, College of Dentistry, Lincoln, Nebraska, October, 1980; (Grant LM02911, National Library of Medicine, Bethesda, MD).

(13) McCloskey, M., A. Caramazza, and B. Green. Curvelinear motion in the absence of external forces: Naive beliefs about the motion of objects. Science 210:1139-1141, December, 1981.

(14) Nickerson, R.S. Understanding Understanding (Draft). Bolt, Beranek, and Newman, Inc., 10 Moulton Street, Cambridge, MA 02238, February 5, 1982.

(15) Papert, Seymour. Mindstorms: Children, Computer, and Powerful Ideas. New York: Basic Books, 1980.

(16) Perry, Walter. The Open University; Jossey-Bass, San Francisco, 1977.

(17) Reif, F. Cognitive mechanisms facilitating human problem solving in a realistic domain: The example of physics. Unpublished. Physics Department and Group in Science in Mathematics Education, University of California, Berkeley, CA 94720; October 19, 1979.

BIOGRAPHIES

Kathleen M. Fisher is Associate Professor, Biological Sciences - Education at the University of California - Davis and member of the Graduate Group in Science and Mathematics Education, U.C.-Berkeley. She has a Ph.D. in Genetics, has produced several courses for television, and has developed computer systems for individualized testing in large classes. She teaches courses in biology, education, and instructional design. Dr. Fisher was founding Director of the Teaching Resources Center at Davis, Fulbright Scholar to Universiti Sains Malaysia, and Program Associate with the National Science Foundation. She is currently doing research on error factors and the cognitive development of biological knowledge.

Dr. Joseph I. Lipson (Ph.D., Physics, Berkeley), Group Director at WICAT Systems Inc., is currently developing computer based instruction to assist engineers in using engineering analysis computer programs. He has authored more than twenty articles and several book chapters on computers and education. His previous positions include Director of Science Education Development and Research at the National Science Foundation, Vice President for Academic Affairs at the University of Mid-America, and Associate Vice Chancellor for Academic Affairs at University of Illinois-Chicago Circle. Dr. Lipson has also worked with Learning Research Associates, Nova University, and the LRDC, University of Pittsburgh.